



International  
Labour  
Office  
Geneva

# ESTABLISHING AN INDEX INSURANCE TRIGGERS FOR CROP LOSS IN NORTHERN GHANA

The Katie School of  
Insurance

**RESEARCH**  
PAPER No.7

SEPTEMBER 2011

## ESTABLISHING AN INDEX INSURANCE TRIGGER FOR CROP LOSS IN NORTHERN GHANA

### THE KATIE SCHOOL OF INSURANCE<sup>1</sup>

#### ABSTRACT

As a consequence of climate change, agriculture in many parts of the world has become a riskier business activity. Given the dependence on agriculture in developing countries, this increased risk has a potentially dramatic effect on the lives of people throughout the developing world especially as it relates to their financial inclusion and sustainable access to capital. This study analyzes the relationships between rainfall per crop gestation period (planting - harvesting) and crop yields and study the likelihood of crop yield losses. We make recommendations on how this information could be used to develop a trigger for index insurance to help mitigate the financial risks to farmers and lenders who make loans to farmers in Ghana. The focus of this paper is on rainfall and crop yield and explores the potential for a drought loss insurance index trigger. This study concludes by describing limitations and challenges that must be overcome in order to develop such risk management tools and by describing the potential for crop loss index insurance based on area crop yield in northern Ghana.

#### INTRODUCTION

Farming is a major source of income for many people in developing countries. In Ghana it represents 36 percent of the country's GDP<sup>2</sup> and is the main source

of income for 60 percent of the population. Agricultural production depends on a number of factors including economic, political, technological, as well as factors such as disease, fires, and certainly weather. Rainfall and temperature have a significant effect on agriculture, especially crops. Although every part of the world has its own weather patterns, and managing the risks associated with these patterns has always been a part of life as a farmer, recent changes in weather cycles resulting from increasing climate change have increased the risk profile for farming and adversely affected the ability of farmers to get loans.

Farmers in developing countries may respond to losses in ways that affect their future livelihoods such as selling off valuable assets, or removing their children from school and hiring them out to others for work. They may also be unable to pay back loans in a timely manner, which makes rural banks and even microfinance institutions reluctant to provide them with the capital they need to purchase high-yield seeds, and other inputs that increase their yields.

This risk also makes farmers less willing to take chances on new farming techniques that could move them from subsistence to commercial farming or allow them to engage in dry season production through investment in irrigation systems. The reluctance of financial institutions to provide capital to farmers becomes more pronounced as their awareness of climate change (discussed later in this paper) increases and alters the perceived, if not actual, risk of farming. For developing countries that rely greatly on agriculture, the inability of farmers to obtain adequate capital and manage their risks makes it difficult to sustain economic growth. Studies show that insurance is correlated to economic development (Hussels, 2005, Outrevill, 1990) and the connection between lending and the ability of the borrower (or lender) to manage risks is one factor for this correlation.

Managing this risk can open the door to enhanced credit for farming operations. If the risk of default on loans due to declines in crop yields can be reduced by either mitigating the economic consequences for individual farmers from crop loss or by mitigating the exposure to credit default risk for financial institutions, then lenders may be more willing to provide loans to farmers or agricultural cooperatives.

---

<sup>1</sup> The Katie School at Illinois State University recognizes the following people as helping to develop this project and shape this report: James R. Jones, Askar Choudhury Domingo Joaquin, Aslihan Spaulding, Krzysztof Ostaszewski, Genevieve Amamoo Horace Melton, Marjorie Danso-Manu, Richard Bill Mukthar Mahdi, Asliddin Odilov

<sup>2</sup> Earth Trends Country Profiles. <http://earthtrends.wri.org> 2003 p. 1

One risk management tool that has been piloted in a few developing countries is an indexed-based insurance product. An advantage of the indexed insurance product over traditional insurance is that it eliminates the administrative costs of underwriting and claim verification required in traditional insurance, and reduces the moral hazard that is associated with individual loss indemnification.

This project examines the potential for an indexed-based insurance product in Ghana by analyzing data that could provide a useful trigger for such an insurance product. The initial focus is on a product for northern Ghana, especially for managing risks of agricultural losses to maize and rice. Although the initial focus is limited to northern Ghana, and these particular crops, the implications of this research are more far-reaching.

## GHANA PROJECT RATIONALE AND OBJECTIVES

Ghana was chosen for a variety of reasons but mainly because it holds the elements necessary for the successful development of risk management techniques including insurance. Once such techniques and insurance are developed in Ghana, it would then have potential to be replicated and used in other, arguably more challenging countries where food security is of an even greater concern.

Ghana has experienced two decades of sound and persistent growth and belongs to a group of very few African countries with a record of positive per capita GDP growth over the past 20 or more years. Ghana is also on the path to become the first Sub-Saharan African country to achieve the first Millennium Goal (MDG1) of halving poverty and hunger before the targeted year of 2015. In addition, Ghana is still an agriculture-based economy. As mentioned earlier, agriculture in Ghana represents 36 percent of the country's GDP<sup>3</sup> and is the main source of income for 60 percent of the population. The country's recent development is characterized by balanced growth at the aggregate economic level, with agriculture

continuing to form the backbone of the economy (McKay and Aryeetey, 2004).

Agricultural growth in Ghana has been more rapid than growth in the non-agricultural sectors in recent years, expanding by an average annual rate of 5.5 percent, compared to 5.2 percent for the economy as a whole (Bogetic et al., 2007).

Ghana's stable government, yet vulnerable agricultural economy, makes it a good country for an indexed insurance product. Stabilizing agricultural income could help Ghana's neighboring countries, as well as African countries in other regions that may currently be less attractive to foreign private capital (Collier, 2007). Ghana is a country that is politically stable, has relatively easy access to data, and favorable regulation. A well-designed risk management system could allow Ghana to act as a gateway to Africa, for underwriters who are not currently participating in Africa.

According to a British Council research briefing<sup>4</sup> unpredictable rains and variability in planting seasons are causing Ghanaians' crop yields to vary significantly. Some rural Ghanaians consider migration to urban areas to be the only option left to them to address this unpredictability that has vexed farmers and those who rely on agriculture for their livelihood.<sup>5</sup> The interrelation of climate change with other factors is complex and still evolving but the growing evidence that climate change, influenced by carbon emissions from developed countries, places tremendous stress on lesser developed countries that are least equipped to manage the change.

The rainfall correlation to crop loss would likely be expected in a country like Ghana, which relies on

<sup>4</sup> BBC World Service Trust and British Council, *Climate Trends in Ghana*. Research Briefing, September 2009. [http://africatalkclimate.com/sites/default/files/content/files/ghana\\_web.pdf](http://africatalkclimate.com/sites/default/files/content/files/ghana_web.pdf) pp. 1-3.

<sup>5</sup> All climate change impacts described in 'Climate Change in Ghana' are fully sourced from the following references: UNFCCC (November 2007), *Ghana's Experience at Integrating Climate Change Adaptation into National Planning*. Drunen M. A. Van, R. Lasage, and C. Dorland (Cabi Publishing 2006), *Climate Change in Developing Countries: Results from the Netherlands Climate Change Studies Assistance Programme*.

<sup>3</sup> Earth Trends Country Profiles. <http://earthtrends.wri.org> 2003 p. 1

adequate rainfall more than other countries in the world or even other Sub-Saharan countries as only 0.2 percent of farmer land in Ghana is irrigated<sup>6</sup>. Insurance for drought loss could provide greater economic stability for agricultural production and the economies of countries relying on agriculture like Ghana (Roth and McCord, 2008).

Currently very few pre-event risk mitigation solutions exist. Traditional insurance has high transaction costs, adverse selection, poor distribution, and other challenges which have increased the costs and reduced the availability of protection. Furthermore, post-event response in the form of emergency aid, debt forgiveness, and grants are at risk following recent economic crises, and such public capital does not usually help create independent private solutions and can be inequitable and untimely.

One possible solution is an indexed-based insurance product based on local weather indices (rainfall and/or temperature) that are correlated with local crop yields and economic losses. Unlike individual indemnification insurance mechanisms, which have high administrative costs, moral hazards, and adverse selection, this type of financial product yields payouts based on pre-determined indices (such as the amount of rainfall in a particular time and location) which historically is correlated with economic loss and humanitarian need. Another product that is a possible solution is an area-based yield insurance product that insures directly against declines in yields for a given area, such as a district (these two insurance products are discussed in detail later in this report).

The goal of this project was to collect, organize and analyze data on weather, crop yield, crop production, crop prices, and other relevant factors that affect agricultural production and agricultural income in Ghana, and begin to explore the potential for providing more capital to farmers through risk mitigation strategies implicated in this research. Possible products that could be derived from this research include indexed based insurance; weather (rainfall) - index derivative, or possibly an area yield indexed insurance product, based on district wide

crop yields that could be used by farmers or financial institutions.

Some hoped for economic and social outcomes in developing such products include:

- 1) Prevention of vulnerable-but-presently-non-poor farmers from falling into the ranks of the poor following a drought (or related agricultural crisis) from which they do not recover.
- 2) Improved incentives for farmers to build their asset base and climb out of poverty.
- 3) Crowding in of finance from private creditors presently unwilling to lend to farmers because of the risk associated with big shocks like drought

## REVIEW OF EXISTING INDEX INSURANCE USED IN AGRICULTURE

### Comparison to Traditional Indemnity Insurance Mechanisms for Payment of Agricultural Loss

One common risk management technique to address agricultural loss is traditional indemnity insurance. Agricultural risks are often addressed by agricultural insurance (such as crop and livestock insurance), flood insurance, and property and casualty insurance for natural disasters such as hurricanes and earthquakes.

In developed countries, especially Western countries, agricultural insurance is commonly available. Farmers in economically developed countries such as the United States, often manage such risks through crop insurance, which is which is substantially subsidized (by as much as 60 percent in the U.S.) by their governments (Dismuskes et al., 2004). However, according to a USAID report on the potential for developing a weather indexed product in developing countries, this is especially true for small farmers, whose income, farm size, and remote location make traditional crop insurance products unworkable. However, traditional agricultural insurance, like crop insurance is not readily available in many developing countries for the following reasons:

<sup>6</sup> Earth Trends Country Profiles, <http://earthtrends.wri.org>, 2003,p.1.

- Traditional agricultural insurance often requires government support, because correlated risks create the potential for large financial losses that private industry is unwilling to accept. This government support is often lacking in developing countries. Without government support the cost of insurance is likely unfeasible for small farmers (USAID, 2006).
- The cost of the insurance can be economically unfeasible for insurers because of the smaller farm lots and lower limits of liability (and subsequent lower premiums). The loss adjustment costs related to proving a loss can easily be larger than the premium for the risks. Moreover, it is costly to control moral hazard and adverse selection, especially for small-scale firms.
- Covariant risk due to a large percentage of the population involved in agriculture.

For all of these reasons, and others, another risk management technique, index insurance, holds promise especially for agricultural risks in developing countries.

### The Fundamentals of Index Insurance

The main difference between index insurance and traditional agriculture insurance is that loss estimates for the former is based on an index or a parametric trigger for the loss rather than the individual loss of each policyholder as is the case with the latter (Skees et al., 2007). Examples of index insurance used in agriculture include:

- A Malawi index-based crop insurance which measures the amount of rain recorded at local meteorological stations. The insurance pays off farmers loans in whole or in part in case of severe drought. Payouts are automatically made to the bank if the index hits the specified contract threshold at the end of the contract<sup>7</sup>.

---

<sup>7</sup> Weather Index-based Crop Insurance in Malawi, Marc Sadler and Olivier Mahul, 2011, *GFDRR* [www.gfdr.org/drfi](http://www.gfdr.org/drfi)

- A Normalized Difference Vegetation Index (NDVI) constructed from data from satellite images which indicate the level of vegetation available for livestock to consume in northern Kenya. When values (which typically range from 0, 1 to 0.7) fall below a certain threshold, the insurance is triggered<sup>8</sup>.
- A farmer in Peru purchases an area-based yield insurance and receives a payment, if the area (such as a county or district) yield falls below an established trigger yield.
- Individual livestock herders in Mongolia purchase policies from private insurance companies that pay out when local area mortality rates for livestock exceed specified "trigger" percentages up to a maximum exhaustion point<sup>9</sup>.

These examples illustrate different ways in which index insurance can be designed with varying triggers for initiating payouts.

### Challenges in Using Index Insurance

Index insurance may not be an appropriate tool in some circumstances where there is great variance between the index and individual losses. This would be the case in crop loss where the losses of an individual farmer may vary dramatically from the indemnity payout based on the index insurance trigger. This potential mismatch is called *basis risk*. Basis risk occurs when realized losses do not correlate well with the index (KFW report, 2007).

There are three types of basis risk: spatial basis risk (difference in outcomes between the physical places where a loss event occurs and where the index is measured), temporal basis risk (due to the timing of the loss event, the consequences of lack of rainfall may be worse), loss specific basis risk (losses are poorly related to the index). Careful consideration of contract

---

<sup>8</sup>[http://dyson.cornell.edu/faculty\\_sites/cbb2/Papers/IBLI%20PROJECT%20SUMMARY.pdf](http://dyson.cornell.edu/faculty_sites/cbb2/Papers/IBLI%20PROJECT%20SUMMARY.pdf)

<sup>9</sup>[http://www.gfdr.org/gfdr/sites/gfdr.org/files/documents/DRFI\\_Mongolia%20IBLI\\_Jan11.pdf](http://www.gfdr.org/gfdr/sites/gfdr.org/files/documents/DRFI_Mongolia%20IBLI_Jan11.pdf)

design and better data may help mitigate the incidence of basis risk.

### Structuring Index Insurance Contracts to Reduce Basis Risk

When designing an index insurance product it is important to minimize basis risk by finding indices strongly correlated to the risk. Conventional wisdom suggests that a weather index requires long-term, accurate, consistent, reliable data on crop yields and index measure (e.g., rainfall). However, long-term, consistent, reliable, verifiable data is not always available, or easily accessible in many developing countries.

This study examines the potential for a rainfall based index in Northern Ghana based on the data available in those districts making up the northern half of Ghana.

### Key Lessons from Developing Countries Regarding Weather Index

- Weather risk products are challenging for developing countries, because the products require sophisticated markets and regulation. Some of the weather index models require a wide variety of variables including soil type, wind speed, temperature, seed types, and fertilizer type. These models may be viewed as lacking transparency by the market or by regulators.
- Developing countries need improvements in the legal and regulatory environment, including contract law and enforcement.
- Lack of good data systems and data collection.
- Need for educational efforts about the use of weather insurance.
- Product development problems exist because extensive private investment required to develop new index products and markets is not economically justified, because these products can be easily copied and replicated by others that did not have to incur the development costs.

## GHANA PROJECT RESEARCH SITES AND DATA COLLECTED

Ghana produces a variety of crops in various climatic zones which range from dry savanna to wet forest. This research is focused mainly on the northern part of Ghana where there is substantial farming activity. The northern region of Ghana is considered the major bread basket of the country, and is also the most susceptible to the vagaries of the weather, especially the lack of rainfall. Unfortunately past agricultural growth and development has been accompanied by increased income inequality, and poverty abatement is lagging in Northern Ghana (Al Hassan and Diao, 2007).

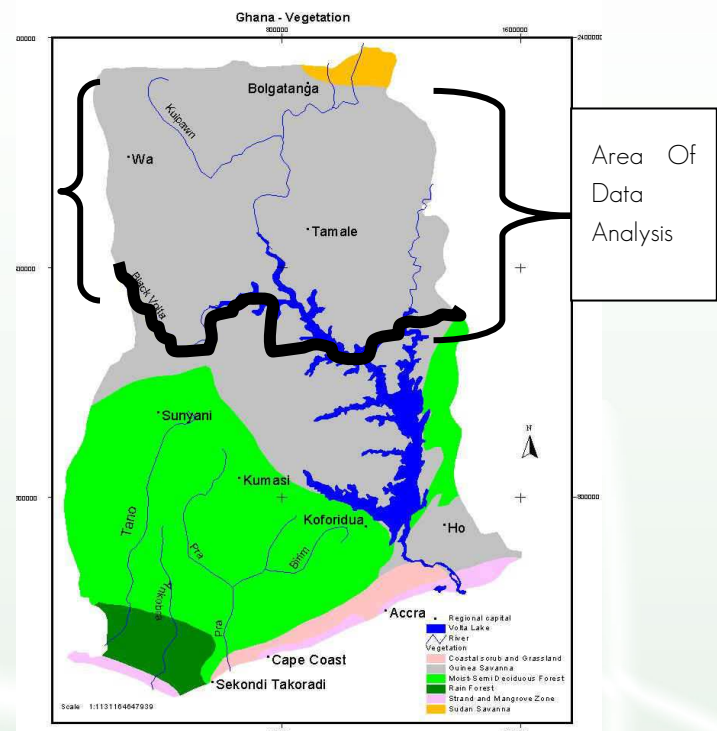
This northern part of Ghana is made up of three main regions; Upper West Region, the Upper East Region and the Northern Region. The largest of these is the Northern Region which incidentally is the largest region in Ghana, covering a land area of about 70,383 square kilometers. However, it has the lowest population density of all ten regions in the country (*PPMED, Ghana, 1991*) with 80% of its people dependent on farming. The major food crops grown here are yam, millet, rice, maize, sorghum, soybeans, groundnut and cassava. Tamale is the administrative capital of the Northern Region and the biggest town in Northern Ghana.

Although Ghana's central and Southern regions have weather cycles consisting of two rainy seasons and a dry season. The northern region experiences only one rainy season (traditionally April - September) and a dry season (traditionally November - April). This one rainy season lends itself to a rainfall insurance index that would be less complicated than one in the central or southern regions which have two rainy seasons. During the dry season, there are also Harmattan winds (dry desert winds) which blow from the northeast from December to March, lowering the humidity with hot days and cool nights. However, like most climates, there is some variability, more so in recent years. Annual rainfall is about 1,100 mm (about 43 in) with a range from about 800 mm to about 1,500 mm. In the Northern region, the Ghana Meteorological Agency (GMA) reported a 10.2% change in the cumulative rainfall between the 30-year

average and that for 2009. Those changes for the Upper East and Upper West regions were -3.5% and -34.5% respectively. All together, the percentage change in rainfall for the northern sector of Ghana was -8.6%.

Average monthly rainfalls over the past 4 decades in the three northern regions has changed. The Upper East Region has a fairly steady rainy season but the Northern Region and Upper Western trended toward a more variable "rainy season" by about one month on average. regions have

The vegetation (see Ghana Vegetation map insert to the right) is classified as savannah woodland, with vast areas of grassland, characterized by drought-resistant trees such as the acacia, baobab, shea nut, dawadawa, mango, neem and mahogany. The area north of the dark line in the map insert to the right is the sector on which this project focuses. The soil in this area is mostly silt or loam, thus having the tendency to get waterlogged during the rainy season but drying up in the dry season. This, however, works well for the farmers since they grow various types of crops: each with its own soil preference. For example, during the rainy season, rice is a preferred crop since it fares very well on marshy land. Yam, on the other hand, is better cultivated when the land is dried out. Although the type of vegetation supports agricultural production quite well, a major hurdle for farmers is maintaining the soil fertility of the land throughout the various farming cycles.



#### Ghana Project Data Sources Collected & Used

Both primary and secondary data were collected and studied for this project. The primary data collection involved meeting with and interviewing potential major stakeholders of the indexed-insurance and microinsurance mechanism (or known locally as a scheme) to understand their motivations, gauge the viability of the scheme and explore potential strategies for implementation. The results of this study are discussed later in this section.

Secondary data was collected on Rainfall, Crop yields, Crop prices and Soil types. Data was collected from The Ministry of Food & Agriculture, which is the main government organization responsible for formulating and implementing agricultural policy in Ghana. The Statistics, Research and Information Directorate (SRID) and Policy Planning Monitoring and Evaluation Division (PPMED) are two of the five directorates through which the ministry carries out its functions. According to information on the Ministry's website, the SRID has as some of its objectives "to initiate and formulate relevant policies/programs for creation of timely, accurate and relevant agricultural statistical database to support decision making" and "to conduct agricultural surveys and censuses covering major agricultural commodities". The PPMED, on the other hand, is responsible for undertaking monitoring

and evaluation of programs and projects under the Ministry.

The statistical service department is an independent government department that is responsible for the collection, compilation, analysis, publication and dissemination of official statistics in Ghana for general and administrative purposes. The Meteorological agency is also the official government entity responsible for collection meteorological data in Ghana.

#### Assumptions and Limitations of Data

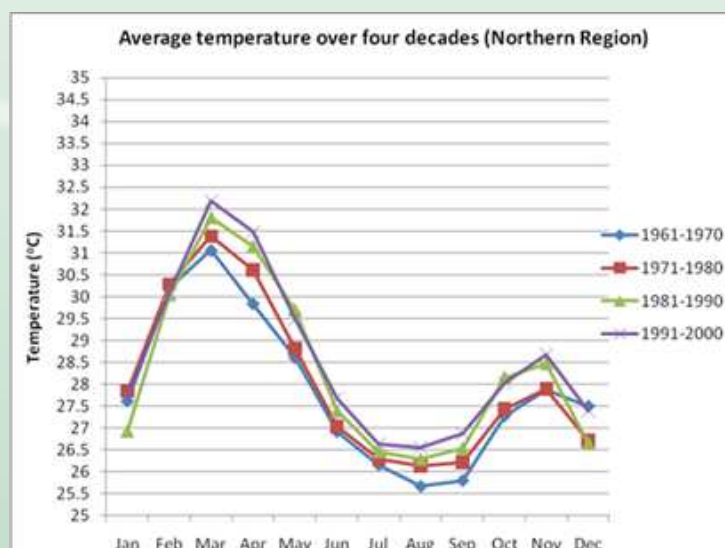
In collecting the data, several assumptions were made, some due to limitations that we came across. Firstly, to be able to design and price an insurance contract based on a weather index, the data for that index must be sufficient. The data used in this research spanned a period of about twenty four years; this would have been sufficient for assessing correlations if the rainfall patterns were consistent. Due to the variability encountered, a longer time period, of about forty years of data, is preferred. However, the project reality is that the data beyond what was obtained is currently only available in paper form and has yet to

be converted to digital form. This project did not have resources for acquiring that data and making that conversion.

Although the data was obtained through all the appropriate government channels and was validated, it is important to keep in mind the potential problem of data being entered incorrectly when it is converted from paper to digital form. For the purpose of this paper, minimal data input error is going to be assumed.

Another limitation is using only a rainfall trigger when temperature data does exist. Unfortunately, temperature data by district is not easily accessible. However, regional data does exist, and the temperature data from the Northern Region as indicated in Exhibit A, shows temperatures have advanced steadily each decade with the latest period showing about a one degree temperature difference over a 40-year time period for the months of March through December. We had to assume that temperature change over time is uniform among districts.

Exhibit A: Average Temperature Change- Northern Ghana (1961-2000)



It was also assumed that the weather stations the rainfall data was collected from were secure and reliable and this may not be true, especially for data from Rainfall Stations. This is not likely an issue with data going forward but this is something that should

be considered if a weather-index insurance product based on historical data. Finally, crop production estimates are not only influenced by rainfall. They are affected by economic factors, morbidity and mortality rates, rural to urban migration which causes farmers to



lose labor for their farms, and occasional government subsidies for inputs. Unfortunately, data on these factors could not be obtained; either because there is no data, or that the data is so incomplete that it makes any useful comparisons difficult.

### Challenges in Collecting Crop & Rainfall Data

A number of challenges were encountered in collecting data on crop yields and production and rainfall. Many are inherent in collecting data in any developing countries but one was unique. Ghana has undergone considerable political redistricting. This redistricting makes comparisons of districts difficult over time. For example, districts of Ghana were re-organized in 1988/1989 in an attempt to decentralize the government and to combat the corruption amongst officials. The reform of the late 1980s subdivided the regions of Ghana into 110 districts, where local district assemblies should deal with the local administration. By 2006, an additional 28 districts were created by splitting some of the original 110, bringing their number up to 138. In February 2008, there were more districts created and some were upgraded to municipal status. This brought the final number to 170 districts in Ghana. There are still only 10 regions.

### Ghana Crop and Rainfall Data Collected

Rainfall Data on rainfall for selected towns was obtained from the Ghana Meteorological Agency. Rainfall data is recorded at the weather stations in all ten regions mainly Ashanti, Brong Ahafo, Central, Eastern, Greater Accra, Upper East, Upper West, Volta and Western regions. There are four types of stations in each region namely Synoptic, Climatic, Agro-meteorological and Rainfall. Synoptic stations collect observations and measurements hourly on all parameters namely rainfall, evaporation, humidity, temperature etc. Climatic Stations are similar to Synoptic stations except that data is collected every three hours on all parameters. Agro-meteorological Stations collects data every three hours, basically on agricultural related parameters such as rainfall, temperature, evaporation, wind speed and direction, precipitation, solar radiation and relative humidity. Rainfall Stations data are collected on rainfall once in twenty-four hours, usually at 09:00 GMT. Rainfall is

the only parameter measured at these stations. These stations are often staffed by part time workers and are considered by some experts to be less reliable. To ensure widespread distribution of stations throughout the country, the following strategies were adopted in collecting the data:

- Apply the principle of stratification (by size) to determine the number of stations for each region.
- Select at least two stations from each region.

<b>Exhibit - Location and Type of Weather Station</b>	
<i>Location where rainfall data collected</i>	<i>Weather station type</i>
Tamale	Synoptic
Bole	Synoptic
Salaga	Agro-Meteorological
Damongo	Climatic
Walewale	Climatic
Gushiegu	Rainfall
Bimbilla	Rainfall
Chereponi	Rainfall
Yendi	Synoptic
Savelugu	Rainfall

Although data was collected from across Ghana, the data analyzed in this first study is from the Northern part of Ghana. The previous exhibit describes the location and type of station the data was collected from.

### Crop Data

Crop yield and prices were obtained from The Statistics, Research and Information Directorate (SRID) and Policy Planning Monitoring and Evaluation Division (PPMED) both of the Ministry of Food & Agriculture. Crop data consisted of crop life cycles (planting and harvesting times), crop production estimates, crop yield and crop prices (wholesale for

rural and urban areas) for various districts. Estimation of yield was conducted using objective measurement techniques. Randomly located square plots were marked out in the field by an enumerator. The square is pegged and lined. Farmers were asked to work on these plots as in other fields on the farm. Produce from these plots were weighed at the time of harvesting by the field worker / enumerator and used as the basis for estimating the yield. The crops inside the plot were harvested by the enumerator at the time the holder harvests the rest of the field. The total production of food crops was determined by estimating the area under cultivation for each crop and the yield rate. The product of these two components was an estimate for the total production of the crop.

Crop production data was from 1985-2007. For the 1985-1991 time period the SRID collected data on a regional basis. As mentioned earlier Ghana has ten regions. The data analysis becomes a bit more challenging moving into later years. For this study the time period of 1992-2007 included SRID data by district in northern Ghana. Fortunately, the northern area of Ghana has only changed from 18 to 20 districts.

Crop price data was also collected. The price data covered the period 1999-2008 (excluding 2001 when data was missing). Wholesale price data was collected on market days usually twice a week. These are averaged to obtain the weekly prices. Weekly prices are also averaged to obtain monthly prices. A simple average of urban and rural prices was computed to obtain a single price for each crop in each region. Regional prices are then averaged to obtain the national price.

An analysis of this crop and rainfall data among various factors was applied and the results of these analyses are reported later in this paper.

### Primary Data

In collecting and analyzing data, the ultimate goal is to be able to provide the foundation to develop a risk transfer technique that would improve the lives of lower income people in Ghana, especially those who rely on agriculture. In-country structured interviews and field visits helped to inform this study. Although it is

beyond the scope of this research report, risk transfer techniques explored in field research included:

- Exploration of need for index-based insurance for farmers and the financial institutions that loaned them money,
- Examination of existing microinsurance products for farmers and market vendors in farming communities,
- Exploration of current and potential non-insurance risk pooling mechanisms for farmers.
- Exploration of interest of Ghana insurers for providing or fronting index insurance
- Exploration of interest by reinsurers doing business in Ghana of interest in providing index insurance or reinsurance

With this in mind, data collection involved exploring the general potential market for various risk transfer techniques for a variety of potential stakeholders and this is reflected in our analysis and our decision to provide two alternative index insurance possibilities.

These various stakeholders provided insightful information that proved to be valuable in our analysis and in the recommendations that we eventually make.

## ANALYSIS OF CROP YIELD AND RAINFALL

In this study, we have considered yields for two crops from two districts namely, Bole and Yendi. Rice and maize were chosen as these are important cash crops for farmers in Ghana. These crops are most likely to correlate highly with the food security of the country. In general, rainfall is supposed to correlate with production of the crops and therefore the yield, especially in areas like northern Ghana that do not rely on irrigation. However, the key factor is timing of rain fall and its frequency during the growing season. Infrequent rainfall with large amount probably will not be as effective as more frequent rainfall with lesser collective quantity. Therefore, both the cumulative rainfall and the frequency of rainfall were analyzed in this paper.

To address yield variability through rainfall index the hypothesis is that rainfall is the main determinant of crop yield and that drought or excessive rain is the source of risk. Thus, the objective of this study is to capture the rainfall and yield relationship in the most accurate way possible. Taking into account that different growth stages have different water needs, it is possible to assume that simple cumulative rainfall might not be effective to portray the correlation with the yield. Improvement in tracking the rainfall-yield relationship in future research may be achieved by assigning different weights to the different growth phases.

Monthly rainfall data from the Northern Ghana region from 1992 to 2007 was collected for our analysis. Due to uneven distribution of daily rainfall, monthly rainfall data is used to identify the correlation. We have calculated monthly cumulative rainfall from the daily rainfall amount. Similarly, we have also calculated monthly frequency of rainfall by counting number of days rainfall occurred. Maize and rice are the major food crops grown in this region and most of it is grown during the rainy season, which runs from April through September. The data on district level maize and rice yield is collected from the Ministry of Agriculture, Government of Ghana. Rainfall from the Bole and Yendi districts' rain stations in the northern region was analyzed as these districts had the most

complete data (see Appendix C for location of these districts). The objective of this preliminary analysis is to observe if there is any correlation exists between monthly cumulative rainfall or monthly frequency of rainfall and the crop yield (maize or rice). This is to help develop in future a weather indexed insurance product in Ghana. At this stage of our analysis, we are only exploring data transformations and the factors' relationships between crop yield and rainfall due to the nature of non-normality and may be an existence of non-linearity.

### Research Results

Descriptive statistics of rice and maize yield in conjunction with frequency and cumulative rainfall are presented in Table 1 for Bole district and for Yendi district in Table 2. Average maize and rice yields are 1.33mt/ha, 1.75mt/ha and 1.11mt/ha, 2.07mt/ha for Bole and Yendi districts respectively; suggesting that there is no apparent difference in yields due to different districts. Average monthly rainfall both in terms of frequency and cumulative is highest in September (215 mm and 266 mm for Bole and Yendi respectively). However, there is a great degree of variation in the cumulative rainfall in Yendi district compared to Bole district. More specifically, the highest standard deviation of cumulative rainfall in Yendi is twice as much as Bole (126 mm vs. 63 mm).

Table 1: Summary statistics of rainfall and yield of maize and rice. (Bole District: Monthly cumulative (in mm) and frequency of rainfall: 1992-2007)

Variable	N	Mean	Std Dev	Min	Max	Variable	Mean	Std Dev	Min	Max
MAIZE_Y	16	1.33	0.33	0.91	2.00					
RICE_Y	16	1.75	0.58	0.40	2.70					
T_Jan	16	4.62	12.74	0.00	50.80	F_Jan	0.44	0.63	0.00	2.00
T_Feb	16	11.66	18.06	0.00	59.70	F_Feb	0.75	1.00	0.00	3.00
T_Mar	16	35.84	31.28	0.00	118.20	F_Mar	3.50	1.97	0.00	8.00
T_Apr	16	115.67	46.91	17.00	175.10	F_Apr	7.81	1.38	5.00	10.00
T_May	16	123.22	49.11	38.70	190.40	F_May	9.88	1.75	7.00	14.00

T_Jun	16	136.39	5402	48.00	235.10	F_Jun	11.31	3.18	500	16.00
T_Jul	16	139.33	5321	49.60	244.40	F_Jul	11.00	2.80	6.00	17.00
T_Aug	16	162.61	6295	82.30	268.40	F_Aug	14.13	3.91	8.00	22.00
<b>T_Sep</b>	<b>16</b>	<b>214.47</b>	5904	118.60	304.10	<b>F_Sep</b>	<b>16.44</b>	1.97	13.00	20.00
T_Oct	15	97.67	53.52	44.10	260.50	F_Oct	9.47	3.27	5.00	16.00
T_Nov	15	28.72	25.64	0.00	74.00	F_Nov	2.53	1.85	0.00	6.00
T_Dec	15	5.65	14.75	0.00	55.00	F_Dec	0.53	0.83	0.00	2.00

Note: T\_Month is the monthly cumulative rainfall in mm for that month.

F\_Month is the monthly frequency (number of times) of rainfall for that month.

Table 2: Summary statistics of rainfall and yield of maize and rice. (Yendi District: Monthly cumulative (in mm) and frequency of rainfall: 1992-2007)

Variable	N	Mean	Std Dev	Min	Max	Variable	Mean	Std Dev	Min	Max
MAIZE_Y	16	1.11	0.36	0.10	1.58					
RICE_Y	16	2.08	0.35	0.83	2.40					
T_Jan	16	6.97	13.70	0.00	45.60	F_Jan	0.44	0.63	0.00	2.00
T_Feb	16	3.99	7.96	0.00	28.10	F_Feb	0.69	0.95	0.00	3.00
T_Mar	16	24.21	21.85	0.00	67.80	F_Mar	2.44	1.36	0.00	5.00
T_Apr	16	94.63	35.68	45.20	158.30	F_Apr	6.25	1.77	4.00	9.00
T_May	16	123.58	30.80	73.50	177.10	F_May	9.81	2.01	5.00	13.00
T_Jun	16	172.04	49.61	101.80	287.60	F_Jun	12.94	2.02	10.00	17.00
T_Jul	16	163.40	55.85	62.70	249.50	F_Jul	14.19	2.95	9.00	20.00
T_Aug	16	226.75	105.50	67.50	395.40	F_Aug	17.63	3.01	12.00	22.00
<b>T_Sep</b>	<b>16</b>	<b>265.99</b>	126.45	0.00	613.50	<b>F_Sep</b>	<b>16.94</b>	5.73	0.00	23.00
T_Oct	16	95.40	44.30	32.30	196.80	F_Oct	10.63	2.78	6.00	17.00
T_Nov	16	8.89	16.34	0.00	51.50	F_Nov	1.19	1.47	0.00	5.00
T_Dec	16	0.76	2.70	0.00	10.80	F_Dec	0.19	0.54	0.00	2.00

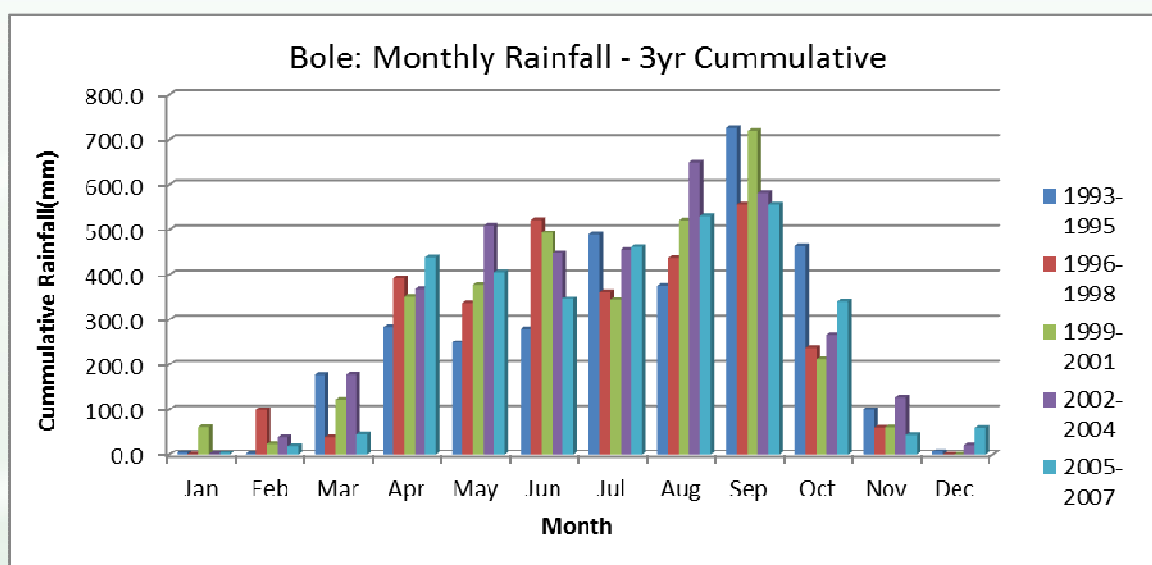
Note: T\_Month is the monthly cumulative rainfall for that month.

F\_Month is the monthly frequency (number of times) of rainfall for that month.

It is observed that there is a steady upward trend in cumulative rainfall in Bole until 2004 for the month of

May and a similar pattern also exists for August (see Graph 1).

Graph 1: Bole Monthly Rainfall



This increase in cumulative rainfall is also visible for the month of April. To understand this change in trend further we have calculated and presented bi-variable correlations in Tables 3 and 4.

We have found that cumulative rainfall during the months of April and August have positive trend (0.50 and 0.46 respectively) and statistically significant at 10% in Bole (Table 3a).

Table 3a: Correlation of cumulative rainfall (mm) in Bole and Yendi from 1992-2007

	T_Jan	T_Feb	T_Mar	T_Apr	T_May	T_Jun	T_Jul	T_Aug	T_Sep	T_Oct	T_Nov	T_Dec
<b>Bole(Year)</b>	0.02	0.01	-0.08	0.50	0.40	0.15	0.05	0.46	-0.40	-0.09	-0.21	0.43
	0.93	0.96	0.77	0.05	0.12	0.58	0.86	0.08	0.12	0.75	0.46	0.11
<b>Yendi(Year)</b>	0.10	0.43	0.09	0.65	-0.14	0.01	0.25	-0.10	-0.01	0.04	-0.02	0.41
	0.72	0.09	0.73	0.01	0.59	0.97	0.35	0.72	0.98	0.89	0.94	0.12

Table 3b: Correlation of frequency of rainfall in Bole and Yendi from 1992-2007

	F_Jan	F_Feb	F_Mar	F_Apr	F_May	F_Jun	F_Jul	F_Aug	F_Sep	F_Oct	F_Nov	F_Dec
<b>Bole(Year)</b>	0.06	0.14	-0.15	0.29	0.47	0.28	0.24	0.25	-0.20	-0.13	0.36	0.31
	0.84	0.61	0.58	0.28	0.07	0.29	0.37	0.35	0.47	0.65	0.19	0.27
<b>Yendi(Year)</b>	0.41	0.20	-0.17	0.09	-0.05	0.14	0.17	-0.07	-0.07	-0.10	-0.06	0.35
	0.11	0.46	0.53	0.73	0.87	0.62	0.53	0.78	0.79	0.71	0.82	0.19

Frequency of rainfall also has upward trend for the month of May. Similarly, there is an upward trend in

cumulative rainfall present during the months of February and April in Yendi (0.43mm and 0.65mm). In

any case, these trends raise serious concerns for developing policies to address productivity of crops in Ghana.

Table 4a: Correlations between cumulative or frequency of rainfall with Maize and Rice yield

(Bole District: Monthly rainfall data-- 1992-2007)

	T_Jan	T_Feb	T_Mar	T_Apr	T_May	T_Jun	T_Jul	T_Aug	T_Sep	T_Oct	T_Nov	T_Dec
MAIZE_Y	-0.28	0.06	0.47	0.04	0.27	0.02	0.03	0.30	-0.13	-0.04	0.39	-0.12
	0.29	0.82	0.07	0.89	0.30	0.93	0.91	0.25	0.64	0.88	0.15	0.66
RICE_Y	0.44	0.07	0.53	-0.57	0.37	-0.38	0.38	0.10	0.15	0.37	-0.01	-0.05
	0.09	0.80	0.03	0.02	0.15	0.15	0.14	0.71	0.57	0.17	0.97	0.87
	F_Jan	F_Feb	F_Mar	F_Apr	F_May	F_Jun	F_Jul	F_Aug	F_Sep	F_Oct	F_Nov	F_Dec
MAIZE_Y	-0.13	0.32	-0.14	-0.02	0.13	0.21	0.14	0.31	0.35	-0.13	0.31	0.28
	0.63	0.23	0.59	0.94	0.62	0.42	0.62	0.25	0.19	0.64	0.26	0.31
RICE_Y	0.45	0.17	0.17	-0.23	-0.05	-0.17	-0.21	0.36	0.42	0.28	-0.25	0.17
	0.08	0.54	0.52	0.40	0.87	0.53	0.44	0.17	0.10	0.31	0.37	0.55

Nonetheless, these results provide us some insights into the possible correlations between crop yield and cumulative rainfall and may be also frequency of rainfall. In fact, some preliminary analysis (results not reported) implementing forward, backward, and mixed stepwise methods to select a regression model using significance level as a criterion to add variables into the model or delete variables from the model indicate high  $R^2$  (between 50% to 70%). These findings are consistent with the hypothesis that cumulative rainfall on a monthly basis is an effective indicator for

crop yield. Therefore, the results of this study suggest that a rainfall based insurance product may be a viable option for the northern region of Ghana, at least in some districts for crops like maize. However our hypothesis that districts in northern Ghana would just need a single trigger for water deficits in a given period (i.e drought insurance) may need to be revised to contemplate a double trigger, with the second one based on too much rainfall in given period. This is discussed more in the conclusions.

Table 4-b: Correlations between cumulative or frequency of rainfall with Maize and Rice yield

(Yendi District: Monthly rainfall data in mm-- 1992-2007)

	T_Jan	T_Feb	T_Mar	T_Apr	T_May	T_Jun	T_Jul	T_Aug	T_Sep	T_Oct	T_Nov	T_Dec
MAIZE_Y	-0.10	-0.06	0.04	-0.03	0.43	-0.15	-0.17	-0.17	-0.70	0.26	0.00	0.18
	0.72	0.82	0.88	0.91	0.10	0.57	0.52	0.52	0.00	0.32	1.00	0.52
RICE_Y	-0.41	0.14	0.13	-0.21	-0.10	-0.24	-0.01	0.21	-0.14	-0.02	-0.57	0.08
	0.11	0.59	0.64	0.44	0.70	0.37	0.98	0.43	0.60	0.95	0.02	0.77
	F_Jan	F_Feb	F_Mar	F_Apr	F_May	F_Jun	F_Jul	F_Aug	F_Sep	F_Oct	F_Nov	F_Dec
MAIZE_Y	0.08	-0.29	0.22	-0.05	0.20	0.03	0.09	-0.46	-0.36	0.21	0.02	0.16
	0.76	0.27	0.41	0.84	0.45	0.93	0.75	0.07	0.17	0.43	0.94	0.56
RICE_Y	-0.22	0.04	0.15	-0.13	-0.36	-0.42	0.23	0.16	-0.10	-0.15	-0.15	0.12
	0.41	0.88	0.58	0.63	0.17	0.10	0.39	0.57	0.70	0.57	0.58	0.66

## SIMULATION OF AREA YIELD CROP INSURANCE PRODUCT

Introduction to Area Yield Crop Insurance As stated previously, a number of complications and limitations exist with weather index insurance. Many of the weather index insurance projects initiated in Africa never left their pilot stages (Skees, 2007)<sup>10</sup>. In addition, an issue exists as to the applicability of an index across geographic districts. In our study we described that the rainfall in two districts of northern Ghana (Bole and Yendi) had some similarities but also significant differences. In fact, the yield for maize in these districts was inversely correlated (see Graph 2). Such differences indicate a need for a district level index which can become a bit challenging for both technical development and marketing so many weather index products in one region of a country. Researchers are now re-examining the potential for area-based yield insurance. The idea of an area based index product which pays out based on the outcome of yields in a well-specified geographic area rather than the outcome of an individual farmer's yield is not new and was introduced as early as 1920, by an Indian scholar and refined later by American scholars<sup>11</sup>. Sweden offered area-yield insurance in the 1950s while area-yield insurance was added to the portfolio of insurance products for the U.S. crop insurance program with a pilot program in 1993.

In the U.S., area-yield products are often as heavily subsidized as traditional agricultural insurance products. The advantage of index insurance over traditional insurance depends on the homogeneity of the area. Research suggests that index insurance performs better than traditional multiple peril crop insurance in more homogenous production regions and for certain crops such as sugar and beets (Barnett et al., 2005). The advantage that area based yields have over individual farm yield insurance products is that they do not have the moral hazard or high administrative costs of a farm yield product. The advantage that it may have over a weather index is

lower basis risk because the trigger is based on yield rather than a variable simulating yield. This is especially true if the policyholder for such insurance has risks representing an entire region such as a farm cooperate or a financial institution desiring to protect against defaults of farm loans made over an entire district. Another advantage, from a policyholder perspective, is that an area yield product would be multi-peril, covering losses from pests or fires, not just weather-related events.

The disadvantages to of an area yield based insurance product to weather index products are 1) timing of determining yield, and 2) the accuracy of the actual area yield number. In most countries the weather information is gathered daily and a determination as to whether a triggering event has occurred can happen quickly. Yield calculations are often made many months after a harvest. Weather information with modern equipment found in many developing countries, including Ghana, provides accurate, objective data that does not rely on human judgment, or even significant labor. Yield calculations, depending on the method employed, rely on professional judgment and can be labor intensive. In some countries yields are self-reported (which has an inherent component of moral hazard). In other countries yields are estimated by using various sampling techniques such as Yield Component Method.<sup>12</sup> These random sampling techniques require well-conceived sampling methods and may involve considerable judgment as well as reliable and consistent labor to sample the fields. In Ghana, production (the numerator for crop yield) is determined by the actual amount of grain delivered to mills. (Left unaccounted for is the crop consumed. For our simulation we assumed that rate of area consumption remained the same.) The area cropped (which is the denominator for calculated yield) is determined by agricultural extension agents that serve a specified number of farmers.

Despite the disadvantages, an area based yield product may still be the best solutions, and for that reason we have included in this section an illustration

<sup>10</sup> This topic of having few successful weather index products in Africa was also mentioned by speakers at the 2009 International Microinsurance Conference in Senegal.

<sup>11</sup> Chakravarti, J. S. (1920). *Agricultural Income: A Practical Scheme Suited to Indian Conditions*. Banaglore, India: Government Press.

<sup>12</sup> <http://www.ag.ndsu.edu/procrop/crn/cestyd09.htm>

of how simulation modeling can be used in pricing and communicating the desirability of crop yield insurance products in a developing country which may have limited production data (in our case we were dealing with an "N" of 16 years for many of the northern districts of Ghana).

### Simulation of Application of Area Crop Yield Insurance for Two Ghana Districts

This study examines the potential for area-based yield insurance in northern Ghana using the same crop yield data and districts analyzed in for rainfall in northern Ghana. We discovered in our in-country field visits and interviews a desire by microfinance institutions and rural banks to mitigate their portfolio risk related to farm loans. In the following analysis, we view the policy as being written for a financial institution rather than an individual farmer. In the conclusions, we discuss the rationale for this and some of the implications and potential unintended consequences of such an approach.

Consider a crop yield insurance product which pays out 100 currency units when the actual district yield  $Y$  is lower than the guaranteed yield,  $Y_g$ .

$$Payout = \begin{cases} 100 & \text{if } Y < Y_g \\ 0 & \text{otherwise} \end{cases}$$

Let us estimate the pure premium rate for the above product with  $Y_g = 50\%$ ,  $60\%$ ,  $70\%$ , and  $80\%$  of historical yield, in the case of maize for two districts in Ghana, Bole and Yendi. Both districts are located in Ghana's northern region. Bole's average maize yield of 1.36 metric tons per hectare is almost 20% higher than Yendi's, which averages only about 1.11 metric tons per hectare. We assume that the yield distribution based on the most recent sixteen-year period (1992-

2007) is a good approximation to yield distribution in the rating period.

There are different distributions which could have generated the observed yields. We use the Chi-square goodness of fit statistic to select the distribution that fits the data best. Candidate distributions are restricted to parametric distributions that are bounded at zero and we estimate the parameters using maximum likelihood techniques. The best fitting distribution turns out to be the lognormal distribution for Bole, and the Weibull distribution for Yendi. For comparison, we fit the Lognormal, the Gamma, and the Weibull distributions to the historical yields of both districts in Tables 4a and 5b. All three distributions cannot be rejected as the distribution generating the observed yield data at the 5% significance level.

Table 6 illustrates the sensitivity of expected loss payouts to the choice of yield distribution. For each distribution we used @Risk simulation, with 10,000 iterations, to estimate the expected payouts. Assuming a desired limit of coverage is 100 units for a lending institution, the expected payouts are presented in Table 6. For both districts, the expected loss payouts are lowest under the respective best fitting distribution, lognormal for Bole and Weibull for Yendi. Overall expected loss payments are lower for Bole compared to Yendi. Of particular concern is how significant differences in the expected payouts are depending on which distribution is selected. For example, with an elected coverage of 70 percent of mean yield, the expected payout for 100 units of coverage is 7.78 under Lognormal distribution and 14.28 under Weibull distribution. Differences in loss probabilities imply differences in expected loss payment, everything else being equal.

Table 6a: Bole Expected Loss

Fixed Payout Case	Elected Coverage	$Y_g$	Payout	Expected Payout Payout x Prob( $Y < Y_g$ )		
				LOGNORMAL	GAMMA	WEIBULL
	80%	1.09	100	19.97	20.24	23.52
	70%	0.95	100	7.78	8.87	14.28
	60%	0.82	100	1.85	2.77	7.81
	50%	0.68	100	0.2	0.53	3.74



Table 6b: Yendi Expected Loss

Fixed Payout Case Elected Coverage	Yg	Payout	Expected Payout Payout x Prob(Y<Yg)		
			WEIBULL	GAMMA	LOGNORMAL
80%	0.89	100	26.98	37.66	42.5
70%	0.78	100	17.36	28.14	34.13
60%	0.67	100	10.16	19.2	25.38
50%	0.55	100	5.27	11.54	16.78

The significance is confirmed in Table 7, which shows that the upper 95% confidence limit for the estimated loss probability is lower than the lower 95% confidence limit under Weibull distribution. Therefore in Bole a higher premium charge would occur if a

Weibull distribution is assumed while in Yendi the higher charge would be expected using a Lognormal distribution. This illustrates the importance of understanding the true distribution.

Table 7a: Illustrating Upper and Lower Ends of the Expected Payout at a 95% confidence interval

Elected Coverage	Yg	Payout	LOGNORMAL		GAMMA		WEIBULL	
			Lower 95% CL	Upper 95% CL	Lower 95% CL	Upper 95% CL	Lower 95% CL	Upper 95% CL
80%	1.09	100	19.19	20.75	19.45	21.03	22.69	24.35
70%	0.95	100	7.25	8.31	8.31	9.43	13.59	14.97
60%	0.82	100	1.59	2.11	2.45	3.09	7.28	8.34
50%	0.68	100	0.11	0.29	0.39	0.67	3.37	4.11

Table 7b: Illustrating Upper and Lower Ends of the Expected Payout at a 95% confidence interval

Elected Coverage	Yg	Payout	WEIBULL		GAMMA		LOGNORMAL	
			Lower 95% CL	Upper 95% CL	Lower 95% CL	Upper 95% CL	Lower 95% CL	Upper 95% CL
80%	0.89	100	26.11	27.85	36.71	38.61	41.53	43.47
70%	0.78	100	16.62	18.10	27.26	29.02	33.20	35.06
60%	0.67	100	9.57	10.75	18.43	19.97	24.53	26.23
50%	0.55	100	4.83	5.71	10.91	12.17	16.05	17.51

One particular concern to financial institutions is the fact the loan default rates tend to increase the more that the actual yield falls below historical average. Thus, desired payouts would be larger, the greater the shortfall between actual yield and the proven historical yield. One way to address this is to permit coverage limits to increase to cover a larger percentage of a lender's farm loan portfolio. An example of how such a product might look is given in Table 8. (The expected payout is just a scaled up version of Table 6.) For instance, assuming Lognormally distributed yields, if the desired payoff is 400 when Bole's actual yield falls below 50% of

historical average, then the expected payout of 0.80 is just 4 times the expected payout of 0.20 when the desired payoff is 100. Similarly, the confidence intervals in Table 9 are just scaled versions of the corresponding intervals in Table 7. These estimates assume that the yield distribution based on the most recent sixteen-year period (1992-2007) is a good approximation to yield distribution in the rating period. This may be a reasonable assumption if in fact the yield distributions are stationary. In countries where yields trend upwards, detrending is required to establish a trigger that is fair to policyholders. This issue is one of the next items in the research agenda.

Table 8a: Bole Expected Loss Payments

Table 8a: Bole Expected Loss Payments Payout Decreasing with Yg			Expected Payout Payout x Prob(Y<Yg)		
Elected Coverage	Yg	Payout	LOGNORMAL	GAMMA	WEIBULL
80%	1.09	100	19.97	20.24	23.52
70%	0.95	200	15.56	17.74	28.56
60%	0.82	300	5.55	8.31	23.43
50%	0.68	400	0.80	2.12	14.96

Table 8b: Yendi Expected Loss Payments

Table 8b: Yendi Expected Loss Payout Decreasing with Yg			Expected Payout Payout x Prob(Y<Yg)		
Elected Coverage	Yg	Payout	WEIBULL	GAMMA	LOGNORMAL
80%	0.89	100	26.98	37.66	42.50
70%	0.78	200	34.72	56.28	68.26
60%	0.67	300	30.48	57.60	76.14
50%	0.55	400	21.08	46.16	67.12

Another issue is how to work with differences across districts and across crops. For example, maize yield in Bole is negatively correlated with that of Yendi (Graph 2). Although challenging for developing an index, this presents an opportunity for risk reduction on the part of an insurers underwriting micro finance units or rural banks in Bole and Yendi. Similarly, these

financial institutions may be able to reduce their risks by diversifying their loan portfolio. Finally, this simulation looked at just one crop. In most situations farmers grow different types of crops concurrently and sequentially. This would likely mean that defaults rates would be even lower if yields for multiple crops are not highly correlated

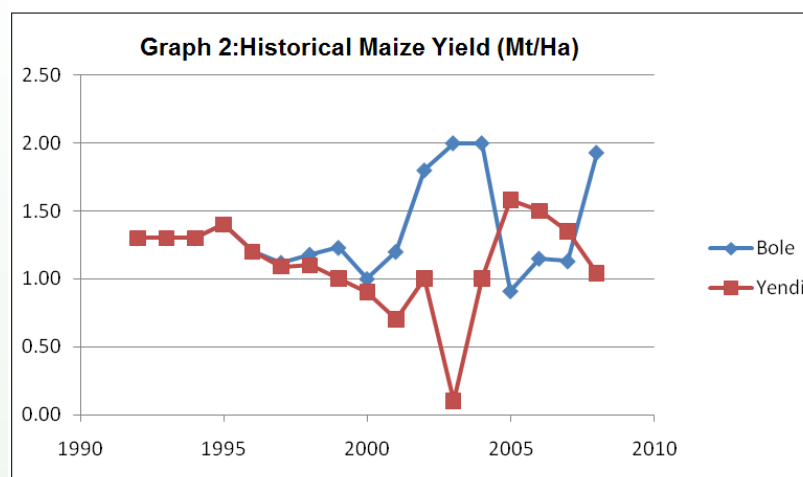
Table 9a: Bole expected loss payments at 95% confidence interval

Table 9a: Bole 95% Confidence Interval Expected Loss Payments								
Elected Coverage	Yg	Payout	LOGNORMAL	LOGNORMAL	GAMMA	GAMMA	WEIBULL	WEIBULL
			Lower 95% CL	Upper 95% CL	Lower 95% CL	Upper 95% CL	Lower 95% CL	Upper 95% CL
80%	1.09	100	19.19	20.75	19.45	21.03	22.69	24.35
70%	0.95	200	14.51	16.61	16.63	18.85	27.19	29.93
60%	0.82	300	4.76	6.34	7.34	9.28	21.85	25.01
50%	0.68	400	0.45	1.15	1.55	2.69	13.47	16.45

Table 9b: Yendi expected loss payments at 95% confidence interval

Table 9b: Yendi 95% Confidence Interval Expected Loss Payments								
Elected Coverage	Yg	Payout	WEIBULL	WEIBULL	GAMMA	GAMMA	LOGNORMAL	LOGNORMAL
			Lower 95% CL	Upper 95% CL	Lower 95% CL	Upper 95% CL	Lower 95% CL	Upper 95% CL
80%	0.89	100	26.11	27.85	36.71	38.61	41.53	43.47
70%	0.78	200	33.24	36.20	54.52	58.04	66.40	70.12
60%	0.67	300	28.70	32.26	55.28	59.92	73.58	78.70
50%	0.55	400	19.33	22.83	43.65	48.67	64.19	70.05

Graph 2: Historical Maize Yield Graph (Mt/Ha)



## LIMITATIONS AND CHALLENGES OF STUDY

In working with the data, several limitations were encountered in this study. These limitations are not unusual for researchers working in developing countries, and in fact Ghana has, on a comparative basis fewer problems than other countries. However, it is important to note these limitations especially in considering the conclusions and the potential areas that need to be researched.

One of the first issues encountered was in obtaining the data. Collecting data is an expensive endeavor and choices were inevitably made in order to best prioritize the data to be obtained. This involved opting for northern region data in lieu of data in other parts of the country. This choice was made because the northern region experiences only one rainy season and drought insurance seemed like a more viable possibility. Furthermore, only limited amount of data is available, and collection of data should continue and expand, so that better and more reliable inferences can be made in future research.

The availability of data in electronic form and the labor involved in obtaining it was an additional challenge. Most of the data that is over twenty years old is currently hard copy in paper files. For the data which has been converted to electronic format, computer viruses have destroyed some of the data, resulting sometimes in one full year of missing electronic data. Paper copies of data do exist, electronic data could be reentered, and the

government is regularly updating and converting to digital form. However, currently only about 15 years of data is available electronically. Oftentimes the data is housed on individual computers in an office and is not networked to a larger data source. This often means that data must be acquired individually from each computer. This is a time consuming and labor intensive process, and requires an in-country researcher to gather the data. (Note: The Statistics Division of the Food and Agriculture Department of Ghana is working to fill in the missing spots and correct inconsistencies in order to have better data to work with and the people we met were helpful and enthusiastic in trying to help us obtain the most up-to-date data).

Although obtaining and converting older hard copy data to digital data may appear to be a likely remedy, the correlations may still prove to be weak, especially given the changes that have occurred in recent years as to the timing of rainfall and planting for various crops. Any correlations would have to be carefully examined in order to determine as they are likely to reflect the current environment of changing climate conditions.

Matching sets of data is required for understanding correlations between variables. The unavailability of matching sets of data and missing crop and rainfall data for several periods impedes the calculation of these correlations in many districts. Data security varies widely by source as well. As mentioned earlier weather stations staffed by volunteers have less

security than other types of meteorological stations. The frequent political redistricting was another challenge because data is recorded by district, but new districts have been added, and without some way to hold the district data constant, it is difficult to find matching data sets to determine correlations. We chose some of the districts which had not undergone re-districting, and therefore permitted comparability of data over time.

Data that is not normal may be required to be normalized before conducting data analysis of correlations. In some district yield trends may require detrending, while other districts they may not. Crop price data must be adjusted to base year to deal with inflation for any analysis of how crop prices respond to changes in yield or weather.

Rainfall-crop yield correlations may be affected by the following factors:

- The location of a rainfall collection station from the center of the district,
- The size and topography of a district,
- The microclimates that exist within a district, and
- The existence of weather bands that bisect a district.

A more detailed, in-country analysis would be required to assess these factors. A potential solution may be to add more rainfall collection sites within a district.

Despite the challenges, this area of research is rich with opportunity for making valuable contributions to the lives of those living in these countries.

## CONCLUSIONS

This study found that over the past two decades there has been a trend toward higher rainfalls in both the two northern districts studied during April and upward trend in both rainfall accumulation and rainfall frequency for May in one of the districts (Bole). It is uncertain how this may affect when farmers decide to plant. However there is a negative correlation in rice yield in Bole for April.

This study also found that there were highly negative correlations (-.70) between monthly cumulative rainfall and maize crop yield and moderately high (-.46)

negative correlations between rainfall frequency and maize crop yield. This finding suggests that waterlogging during flowering and yield formation stages is a more important concern for maize yield than water deficits during the flowering stage for one district in the northern region. This was an unexpected finding and has significant implications on the type of rainfall index trigger(s) that would need to be established. Although the level of statistical significance was not nearly as high, there was some positive correlation between cumulative rainfall and maize in the other district studied for March and May. Further studies on additional districts need to be completed in order to establish whether waterlogging or water deficits have more influence on crop yields in the northern part of Ghana. Outside of insurance, farmers may need to consider the timing of planting. As mentioned earlier in this study, rainfall has shifted and farmers may be able to avoid the issue of water logging during critical flowering stages. Communicating these types of findings to farmers and providing them with information to help them adjust the timing of planting is perhaps one non-insurance solution which could be implemented.

As a way of addressing the complications related to rainfall and yield correlations, an area-based yield case was presented. This seems to have some promise for the development of an insurance product based on area yield as the findings suggested that the probabilities for catastrophic losses below 50 percent of the average yield were fairly low. In addition the case example used was for only one crop. In most cases farmers would diversify with several crops and so one would expect that loan defaults would be less than with a single crop especially when considering crops whose yields are not correlated or even negatively correlated. Although the area yield insurance product might be a bit risky for an individual farmer whose crop yields may not reflect that of the overall area, it would be expected that the losses of lending institution to loan defaults to farmers made throughout a district may be closely correlated to area yield. For this reason, it may be most practical to develop an area yield insurance product that serves microfinance institutions and rural banks that loan money to farmers. In the end, enhancing capital for farmers by mitigating the risks of these lending

institutions might provide the greatest outcome for farmers. In implementing such a product it would be important to measure the extent of farm loans made before and after the purchase of such products to confirm that the product is truly enhancing capital for farmers as one legitimate concern is that the product would be welcomed by financial institutions but would not be used to enhance capital flowing to farmers.

We see a potential for an insurance product to mitigate the risk of crop loss and enhance the flow of capital to farmers. One of the important factors to consider in this is how prices may be affected by yield as well. For example, if prices fall dramatically when yields go up then farmers may be worse off economically. This relationship between crop yield and crop price needs to be further analyzed in order to properly establish the viability of an area yield insurance product in mitigating the risks of defaults on farm loans.

There are a number of ways that farmers can maximize the price received on crops, and there is evidence in Ghana that some financial institutions have assisted farmers with this and this assistance helped both the farmer and the financial institution. A study of ways in which financial institutions combine this type of expertise for farmers in the timing and location for selling crops, as well as incentivizing farmers to use the most effective inputs and farming techniques would be powerful complement to the development, underwriting and sales of an insurance product for crop loss.

## REFERENCES

- Al-Hassan, R. & Jatoo, J. B. (2002, December). "Adoption and impact of improved cereal varieties in Ghana." Paper prepared for the workshop on the Green Revolution in Asia and its transferability to Africa, Tokyo, Japan.
- Al-Kaisi, M.M. and Broner I. (2009). "Crop Water Use and Growth Stages." Retrieved May 4, 2011 from Colorado State University website: <http://www.ext.colostate.edu/pubs/crops/04715.html>
- Appiah, G. (2009, February). "Databank Ghana Consumer Inflation Report" Retrieved 23<sup>rd</sup> July 2009 from website: <http://www.slideshare.net/GeorgeAppiah/databank-ghana-consumer-inflation-report-february-2009>
- Barnett, J.B. & Mahul, O. (2007). "Weather Index Insurance for Agriculture and Rural Areas in Lower-Income Countries", Retrieved 23<sup>rd</sup> July 2009 from <http://www.microinsurancecentre.org>
- Barnett, Barry J., Yingyao Hu, Black, J.L. & Skees, J.R. (2005). Is area yield insurance competitive with farm yield insurance? *Journal of Agricultural and Resource Economics*, 30(2), 285-301.
- Brouwer, C. and M. Heibloem. "Irrigation Water Management: Irrigation Water Needs." FAO Land and Water Development Division Report. Retrieved May 4, 2011 from FAO website <http://www.fao.org/docrep/S2022E/s2022e07.htm>
- Crop Water Information: Maize. Retrieved May 7, 2011 from FAO website at [http://www.fao.org/nr/water/cropinfo\\_maize.html](http://www.fao.org/nr/water/cropinfo_maize.html)
- Chakravarti, J. S. (1920). *Agricultural Income: A Practical Scheme Suited to Indian Conditions*. Bangalore, India: Government Press.
- Dercon, S., Kirchberger, M., Gunning, W.J., & Platteau, J. (2008). *Microinsurance paper no. 1. Literature Review on Microinsurance*. Published by International Labor Organization (ILO).
- Dismukes, R., Bird, J.L., & Linse, F. (2001). "Risk Management Tools in Europe: Agricultural Insurance, Futures, and Options." U.S.-EU Food and Agriculture Comparisons / WRS-04-04. Retrieved May 4, 2011 from ERS website at <http://www.ers.usda.gov/publications/WRS0404/WRS0404d.pdf>
- Garman, M., Blanco, C. and Erickson, R. (2000), "Weather Derivatives: Instruments and Pricing Issues", *Environmental Finance*
- Geman, H. & Leonardi, M. (2005). Alternative approaches to weather derivative pricing. *The Journal of Managerial Finance*, 31(6), 45-71.
- Ghana Statistical Service (2009). National CPI & Inflation rates. Retrieved 20<sup>th</sup> July, 2009 from

website:

[http://www.statsghana.gov.gh/docfiles/CPIRelease\\_pdf/national\\_cpi\\_&\\_inflation\\_rates.pdf](http://www.statsghana.gov.gh/docfiles/CPIRelease_pdf/national_cpi_&_inflation_rates.pdf)

Hartell, J. & Skees, J. (2009). "Pre-Feasibility Analysis: Index-based Weather Risk Transfer in Mali". USAID report.

Hussels, Ward and Zurbregg, 2005, Outrevill, 1990. WEATHER RISK TRANSFER IN MALI.

Martin, S. W., Barnett, J. B. & Coble, K. H. (2001). "Developing and pricing precipitation insurance." *Journal of Agricultural and Resource Economics*, 26(1), 261-274.

Policy Planning Monitoring and Evaluation Division (PPMED), Ministry of Food & Agriculture, Ghana.

Saaka, S. O., & Telly, E. M (1999, May). "National report to the third session of the conference of the parties to the United Nations convention to combat desertification." Paper presented at the national

validation workshop of stakeholders, Bolgatanga, Ghana.

Sharma, A. K, & Vashishtha, A. (2007). "Developing and pricing precipitation insurance." *The Journal of Risk Finance*, 8(2), 112-132.

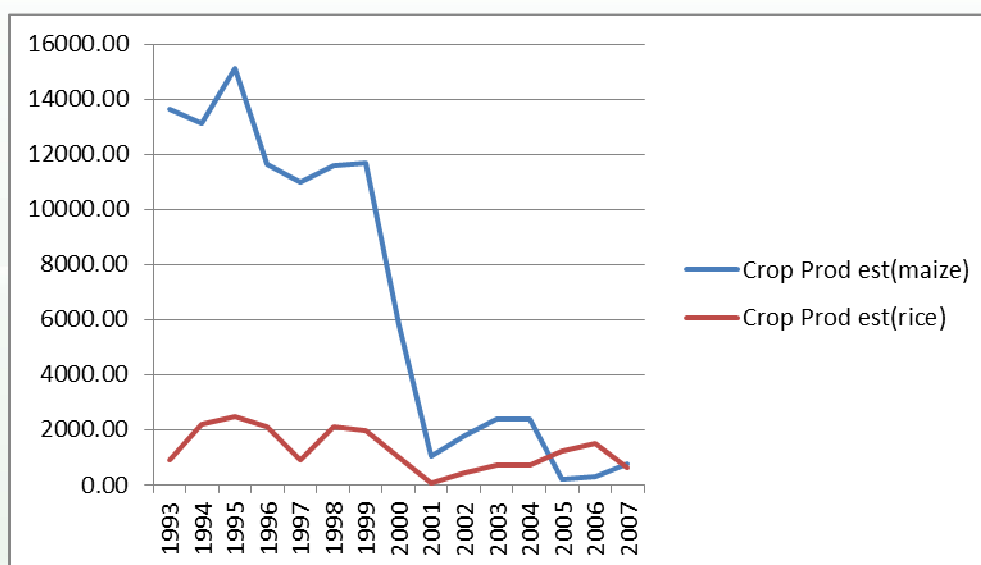
Skees, R. J., & Collier, B. (2008). *The Potential of Weather Index Insurance for Spurring a Green Revolution in Africa*.

Skees, J., Murphy, A., Collier, B., McCord, J.M., & Roth, J. (2007). *Scaling Up Index Insurance, What is needed for the next big step forward?*

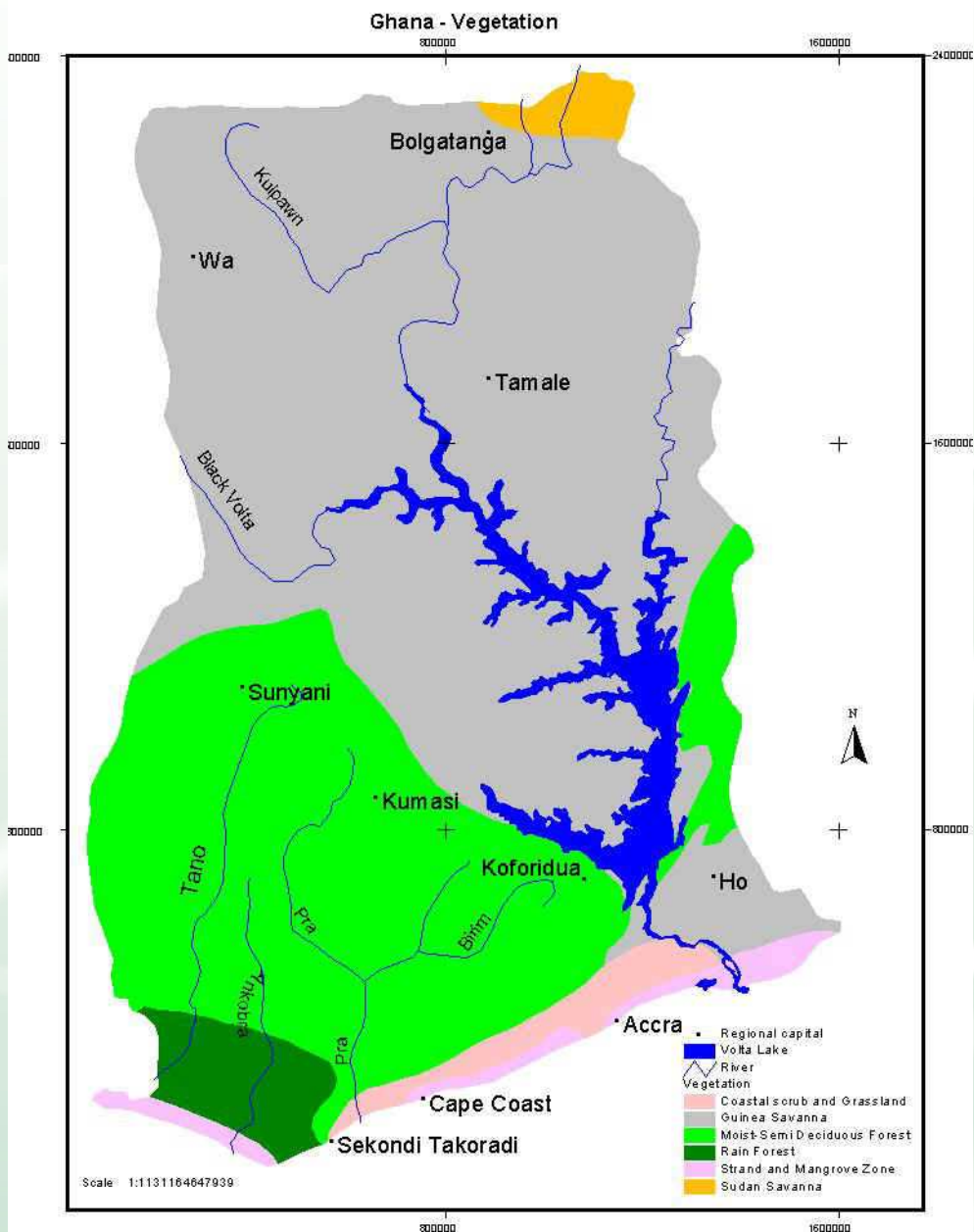
Swadener, P. (1964). "Gambling and Insurance Distinguished." *The Journal of Risk and Insurance*, 31(3), 463-468. Retrieved from <http://www.jstor.org/stable/250940>

The Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture, Ghana.

Appendix A: Graph of Maize and Rice production estimates (1993 - 2007 )



Appendix B. Maps of Northern Ghana





## Appendix C. Map of Northern Districts



The Northern Region of Ghana contains 20 districts. 18 are ordinary districts in addition to 1 municipal and 1 metropolitan district.

1. Bole District
2. Bunkpurugu-Yunyoo District
3. Central Gonja District
4. Chereponi District
5. East Gonja District
6. East Mamprusi District
7. Gushiegu District
8. Karaga District
9. Kpandai District
10. Nanumba North District
11. Nanumba South District
12. Saboba District
13. Savelugu-Nanton District
14. Sawla-Tuna-Kalba District
15. Tamale Metropolitan District
16. Tolon-Kumbungu District
17. West Gonja District
18. West Mamprusi District
19. Yendi Municipal District
20. Zabzugu-Tatale District

Appendix D: Local Classification of Soil types of Ghana

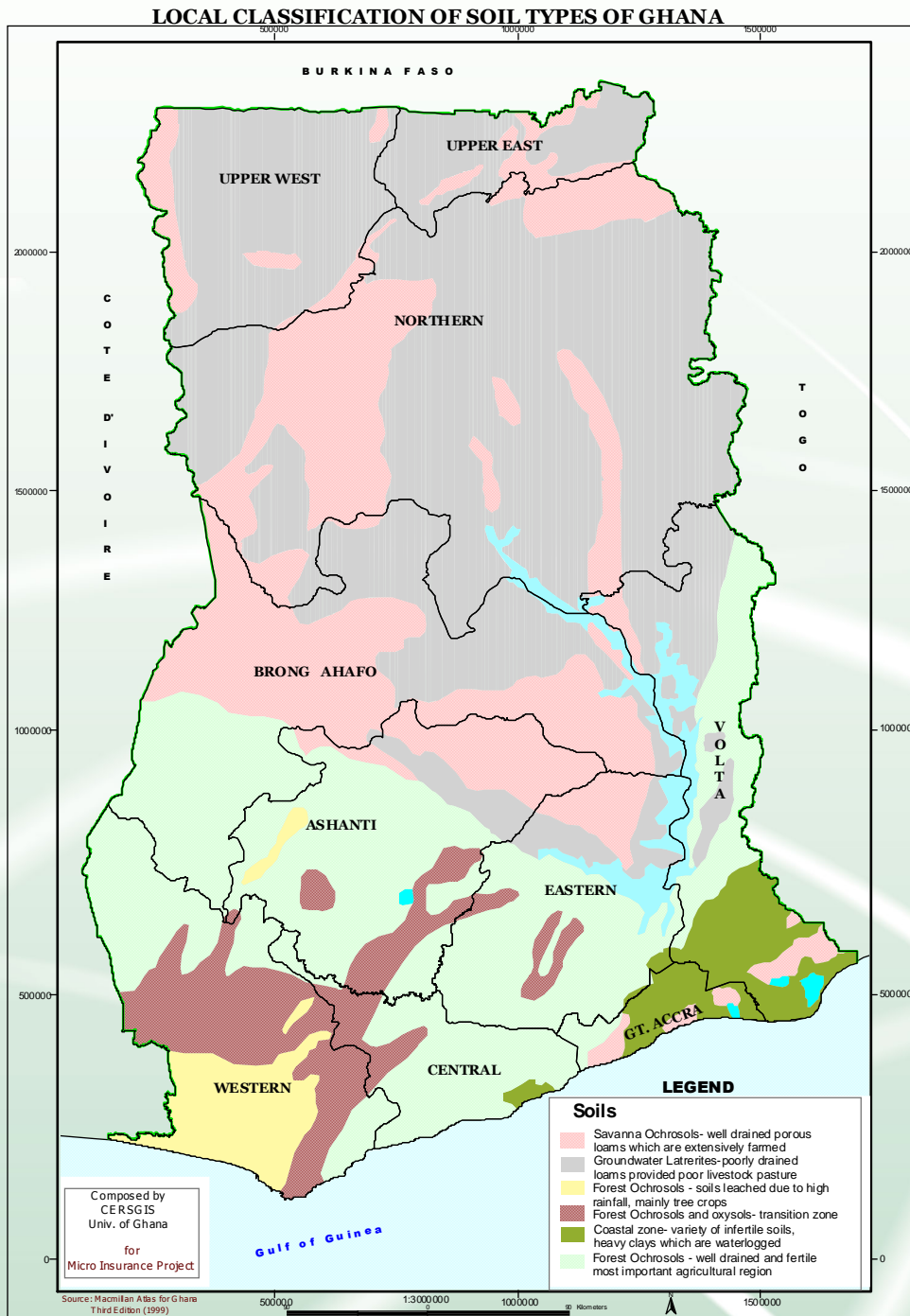


Exhibit A: Average Temperature Change- Northern Ghana (1961-2000)

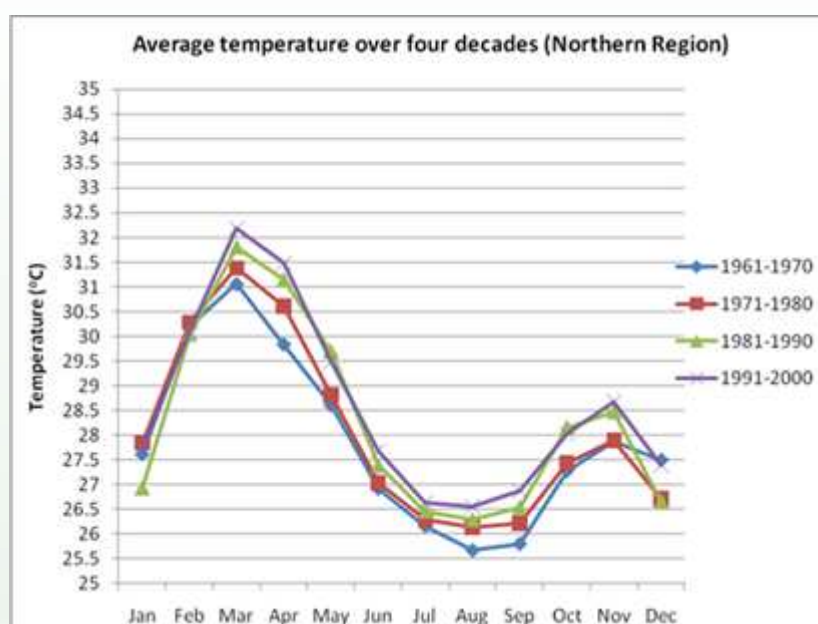


Exhibit B: Life cycles of Maize and Rice in Northern Region of Ghana

Crop	Planting date	Time of harvest	Gestation
Maize	End of March - End of April (major season)	August - September (major crop)	105 days (early maturing )
		December - January (minor crop)	120 days or more (late maturing )
Rice	April - May	Late October - November	4-5 months